A Proposed Communications Architecture for the First Lunar Outpost

Timothy Hanson[1] and Richard Markley[2]

[1]Ecole Supérieure d'Ingénieurs en Informatique et Génie des Télécommunications
1, rue du Port de Valvins
77215 Avon-Fontainebleau Cedex
France

[2]NASA/CalTech Jet Propulsion Laboratory
Pasadena, CA

Abstract: The manned and robotic return to the moon envisioned in America's Space Exploration initiative [7] requires robust and reliable communications. An initial comunications architecture for the Jet Propulsion Laboratories Deep Space Network appropriate for human and robotic exploration of the moon is proposed. Network management can make a major contribution towards establishing a robust and reliable communications system. Economic implementation of lunar communications requires the use of standardized techniques. The need for standardization extends to the communications medium, the communications protocols, and the network management scheme.

Introduction

Robust communication with the moon must be provided. The communications system should be fault tolerant and reconfigurable in the presence of faults. The communications system should be easily expandable. Future missions will not want to abandon misting, equipment, hut instead existing equipment will be incorporated into an expanding lunar communicant ions system, Programmability of the lunar communications processors leads to flexibility as communications requirements change. The use of a programmable data communications scheme provides desirable flexibility and expandability. The Consultative Committee for Space Data Systems (CCSDS) Advanced Orbiting Systems (AOS) standard [2] provides the necessary flexibility and programmability.

Communications need to be provided to the lunar habitat, extrahabitat activity, distributed scientific instruments, and a rover. The habitat, the rover, and the distributed scientific instruments should each he provided with a separate downlink. It is proposed that during periods of extrahabitat activity the astronauts communicate with the earth using the habitat or rover downlink. Within the lunar habitat astronauts will need voice communication troth with the earth, the rover, and any astronauts performing extrahabitat activities. The lunar habitat will need video downlink capability to earth. Scientific instruments inside the habitat will need data communications capability with earth. Monitoring of the habitat requires downlinking engineering data concerning the status of the habitat and its inhabitants. The necessary data rates have been estimated and a communications architecture proposed.

Operational Considerations

Four aspects of the first lunar outpost require communications capability: the lunar habitat, extrahabitat activity, a rover that can be used in either manned or unmanned mode, and scientific experiments distributed on the moon. A separate downlink channel to the earth should be provided for the habitat, the rover, and the distributed scientific instruments. During periods of extrahabitat activity the astronauts should communicate with the earth using the habitat or rover downlink.

The rover can not be expected to remain within line of sight radio propagation distance from the habitat. Also the distributed scientific instruments may be located beyond the distance which radio waves will propagate on the lunar sulfate. These facts anti the expense of lunar radio repeaters make it necessary to provide a separate downlink for the habitat, the distributed scientific instruments, and the rover. The alternative would be to link the rover communications and the distributed scientific instruments back to the habitat to share the habitat downlink.

Consultative Committee for Space Data Systems

The CCSDS AOS (Consultative Committee for Space Data Systems Advanced Orbiting Systems) communications format should be used for lunar communications in order to standardize and promote interoperability [1,2]. The CCSDS AOS recommendation has established six types of service [5,6]. The six types of service are called path, internet, encapsulation, multiplexing, insert, and bitstream service. The path service is intended for high data rate users with relatively fixed interconnections. The internet service is intended for interconnections requiring flexibility.

The CCSDS AOS recommendations have identified three service classes. Grade-1 service operates with a space link ARQ procedure. Grade-2 service is Reed-Solomon block code protected. and is appropriate for compressed audio or video data. Grade-3 service is intended for redundant data sources where bit errors are not critical. Grade-3 might be used for redundant video or audio transmissions.

Two approaches are possible.. in the first approach all science instruments communicate through a central facility that contains the uplink/downlink facility. in the second approach the devices associated with the habitat share a uplink/downlink facility and those devices distant from the habitat are provided with their own independent CCSDS AOS communication link to the earth. CCSDS AOS uses a time division multiplexed stream format that integrates telemetry, voice, and video.

The CCSDS Advanced Orbiting Systems Recommendation

Using the CCSDS AOS format the habitat can be provided with multi-access communications. Within the habitat provision for video, data, voice, and telemetry is necessary. CCSDS AOS integrates video, audio, telemetry, and scientific communications Upon reception by the DSN video and audio needs be demultiplexed from the telemetry and telecommand data streams.

The CCSDS path service can be used for high data rate scientific instruments. The path service, has been developed to optimize the handling of telemetry data. The path service exists to route high volumes of packetized data. The path service transfers variable length application layer service data units across the network. The path service is intended for transferring at moderate to very high data rates, large volumes of structured, delimited data units between fairly static source and destination locations, This service is appropriate for transfer of telemetry from scientific instruments. With the path service pre-established associations known as CCSDS "Logical Data Paths", can be configured because of the known associations between the message source and destination.

The CCSDS AOS data stream can provide video links. CCSDS class-2 path service should be used to transmit compressed video. Class-2 service should be provided. Compressed video and voice signals require protection from error.

The CCSDS internet service can be used for engineering data and data communications. The internet service is intended primarily for intermittently transferring at relatively low data rates. This service can support realtime interactive control and command operations, file transfer, and interactive operations such as electronic mail and remote terminal access.

Communications Flexibility

Variable quality voice and video transmission is an example of communications flexibility. When higher quality voice or video communications are required a larger number of bits per second may be allocated. An addition benefit of flexibility is reconfiguration of the downlinks as a function of time. For instance, during sleep periods the video downlink capability can be used for data transmission When all downlinks are not used simultaneously the bandwidth of the unused downlink may be reassigned Future missions may integrate new experiments or communication needs through the programmability of the downlinks. Network management is a key to these possibilities.

The use of the CCSDS AOS format yields a modular method of increasing communications capacity. Maintaining CCSDS AOS compatibility of the downlinks leads to their interoperability. In the case downlink failure one of the other dowlinks may replace of the failed downlink.

The Radio Frequency Link

S-band has been proposed for lunar communications. The misting JPL DSN 26 meter antennas are S-band capable, At S-band the 26 meter DSN antenna beam covers the entire lunar surface. The link budget allows for low power transmission from the lunar surface with a comfortable margin. The S-band suffers from frequency congestion problems With current systems. X-band is much less congested than S-band. However, at X-band multiple beams may be necessary to communicate with the entire lunar surface. Ka-band is also an alternative. Use of the X-band or Ka-band may be necessary to accommodate future higher rate lunar communications needs and to avoid frequency allocation congestion.

The rover and astronomical instruments should each have sepal-ate RF links. A single RF link can be shared among multiple devices by using earth based polling of the lunar based devices. Polling can allow several highrate devices to share a single radio frequency channel.

Figure 1 The First Lunar Outpost

Lunar Habitat Communications Requirements

Within the lunar habitat astronauts will need voice communication with the earth, the rover, ant] astronauts performing extrahabitat activities. The lunar habitat will need video downlink capability to earth, Scientific instruments inside the habitat will need data communications capability with earth. Monitoring of the habitat will require downlinking engineering data concerning the status of the habitat and its inhabitants.

The lunar habitat should he provided with transmission capability for video, voice, science data, and engineering data. Within the habitat itself an integrated voice, data, video LAN system can be used. The fiber distributed data interface (FDDI), a 100 Mbps optical token ring, can provide a communications medium for the science packages. FDDI-II integrates data, audio, and video. Communication with the earth requires a habitat LAN to CCSDS AOS gateway. Two voice channels, three video channels, two science telemetry channels, and two engineering telemetry channels are proposed. It is proposed that the earth based uplink to the lunar habitat have two channels of digital information and two voice channels.

Within the habitat communications should be provided with commercially available standardized techniques. If multiple optical LANs are used in the lunar habitat asynchronous transfer mode (ATM) switching, may be an appropriate choice for the lunar habitat. Optical fiber can link science packages near the habitat. The cable may have to be buried to protect it from radiation, the rover and the thermal environment. However, the cost of fiber may he prohibitive outside of the lunar habitat.

initially it is proposed to provide the habitat with only one uplink due to the cost of providing several uplinks. The rover and high data reate scientific instruments should be provided with their own separate downlinks. Within the lunar habitat itself the International Standards Organization Open systems interconnection (OS1) model standards should be the underlying communications technology. Habitat communications could be provided using commercially available products. A wireless LAN also could be used in order to extend data communications beyond the confines of the habitat. If multiple optical LANs are used in the lunar habitat ATM switching may be an appropriate choice for the lunar habitat.

Lunar Rover Communications Requirements

The lunar rover can be operated in two modes: manned or teleoperated. Communication capability for rover teleoperation must be provided. Rover teleoperation requires a high data rate. The earth-rover datalink must provide for teleoperation of the rover. The rover will transmit low bit rate stereo images to the teleoperator. Science and engineering data channels will also be necessary for the rover. In unmanned mode the rover downlink should have one engineering data channel, one science telemetry channel, and two low bit rate video channels. When the lunar rover is manned the rover downlink should provide a high quality video channel, a voice channel, a science telemetry channel, and an engineering data channel. In manned mode the rover uplink channel provides one voice channel and one engineering data channel.

"There is a line of sight limitation on rover communication with the habitat. Continuous rover communication with the earth can be maintain ned by using a separate rover antenna allocated its own separate frequency. The expense of repeaters to provide a continuous link between the rover and the habitat is prohibitive.

Distributed Scientific Equipment Communications Requirements

Data communications should be provided for scientific experiments distributed on the lunar surface. Distributed scientific experiments may have high downlink data rates. For instance, the one meter transit telescope should be provided with a downlink of 1 Mbps and a control uplink of 5 kbps. To minimize frequency coordination problems, experiments with a continuous high data rate are allocated their own separate downlink frequency Spectrum instruments with intermittent data can use buffering and earth based polling to coordinate sharing the same frequency allocation, High data rate instruments in the area of the habitat but not inside the habitat itself can be linked with the habitat with fiber optic cable.

Extrahabitat Communications Requirements

During periods of extrahabitat activity voice communications with the earth should be provided through either the habitat or the lunar rover. There will be a line of sight limitation on rover communication with the habitat. Still image transmission can be used for transmission of maps. The astronauts must have either the habitat or the rover in their line of sight to maintain communications with earth.

Command and Control Uplink Communications Requirements

Encryption techniques can provide command and control channel security. The earth based uplink to the lunar habitat should provide two channels of digital information and two voice channels. All of these services should be digital. in the manned mode the rover uplink channel provides one voice channel and one engineering data channel. The distributed scientific instruments should be provided with a 5 kbps control uplink.

Impact on the DSN 26-Meter Subnet

Integrated service, i.e., voice, video, and data is not currently provided by the DSN. Additional switching and routing will be necessary for voice and video. Time delay cannot be introduced into these services. A switching technology new to the DSN, asynchronous transfer mode (ATM) could be introduced. A commercial asynchronous transfer mode (ATM) switch Can be used to sepal-ate and route the data, voice, and video coming from the earth based CCSDS AOS processors. In the ground network voice, video, and data must be routed in different manners. Higher capacity circuits will be necessary between the deep space network 26-meter antennas and JPL. Time delay should not be introduced into the transfer of voice and video signals.

Network Management

Some degree of human control must be exercised over the communications system Network management adds flexibility. The earth moon propagation delay causes problems not encounter ed in an earth based network management system Management hierarchy is a key issue in lunar communications management. A network management system should be provided with in the habitat. The habitat network management system should be interogatable by the earth based network management system.

The data communications objects to be managed are in the management information base m MIB. Use of the MIB allows intervention in data transport functions. A MIB definition is necessary for cinch managed object. One task is the identification of the objects to be managed. in order to generate alarms, 'l'l<Al}s may be generated by network management agents when preassigned network performance thresholds arc crossed.

Figure 2 Earth Based Communications

The earth based network management system may use graphical human interfaces. Management data is collected and is presented to the operators at the ear (1 I based integrated network management system. Software agents in the lunar habitat, rover, scientific instruments, and the DSN should report to an integrated network management system. 'l'he net work system manages faults and detects network problems. Alarms generated by communication system failures should be intelligently filtered. Otherwise one single failure may lead to a confusing string of alarms difficult for operators.

Integrated network management leads to a reduced number of disparate, proprietary, network management systems. Management information is displayed in a consistent manner, Routers in the earth based network may be managed from the network management station. Network management software may be used for active intervention in tbe network.

Conclusion

The 26-meter antennas were previously used by the Apollo missions. The Apollo missions used analog transmission techniques. Entirely digital transmissi on techniques s]1oL1]c] be for the lunar outpost. The CCSDS Advanced Orbiting, Systems Protocols will be used.

In contrast to voice and realtime video, scientific data may be buffered prior to transmission back to JPL. In order to deal with the requirement of realtime voice and video the incorporation of ATM switching into the DSN shoul d be investigated

References

[1] R. Carper and W. Stallings, "CCSDS Telemetry Systems Experience at the Goddard Space Flight Center", *IEEE Netw ork Magazine*, September 1990.

[2] Consultative Committee for Space Data System Standards, "Advanced Orbiting Systems, Networks and Data 1 .inks: Architectural Specification", Blue Book, October 1989.

[3] C.R. Easton, and J.J. Smith, "Data Services for Space Station F reedom", *IEEE Netw ork Magaz ine*, September 1990.

[4] 'J'. Hanson, and R Markley, "Communications Requirements for the First Lunar Outpost", IEEE Southeastcon, Charlotte, North Carolina, April 1993.

[5] 11. Helgert, "Sel-vices, Architectures, and Protocols for Space Data Systems", *Proceedings of the IEEE*, Vol. *79, No.* 9, September 1991.

[6] A, Hooke, "CCSDS Advanced Orbiting Systems: International Data Communications Standards for the Space Station Freedom", *IEEE Netw ork Magazine*, September J 990.

[7] Report of the Synthesis Group on America's Space Exploration Initiative, NASA Document.